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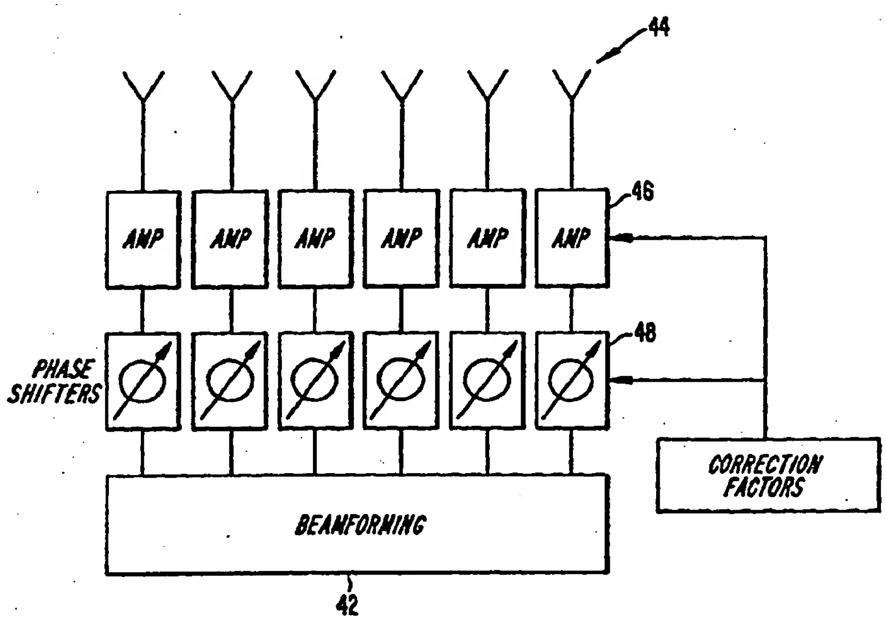

(57) Abstract

A method and apparatus for calibrating the transmission of an antenna array for use in a mobile radio communication system so as to increase the accuracy of the beam shape and direction of the antenna beam are disclosed. First, an input signal is inputted into each antenna section one antenna section at a time. The signal transmitted by each antenna section is then measured and correction factors can be formed for each antenna section. The antenna sections are then adjusted using the correction factors so as to ensure that each section is properly calibrated.

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ANTENNA ARRAY CALIBRATION

Field of the Invention

The present invention relates to an antenna array for use in a base station in a cellular communication system, and more particularly to an antenna array calibration system for improving the performance of base stations.

Background of the Invention

The cellular industry has made phenomenal strides in commercial operations in the United States as well as the rest of the world. The number of cellular users in major metropolitan areas has far exceeded expectations and is outstripping system capacity. If this trend continues, the effects of the rapid growth will soon be achieved even in the smallest markets. Innovative solutions are thus required to meet these increasing capacity needs as well as to maintain high quality service and avoid raising prices. Furthermore, as the number of cellular users increases, the problems associated with co-channel interference become of increased importance.

Figure 1 illustrates ten cells C1-C10 in a typical cellular mobile radio communication system. Normally, a cellular mobile radio system would be implemented with more than ten cells. However, for the purposes of simplicity, the present invention can be explained using the simplified representation illustrated in Figure 1. For each cell, C1-C10, there is a base station B1-B10 with the same reference number as the corresponding cell. Figure 1 illustrates the base stations as situated in the vicinity of the cell center and having omnidirectional antennas.

Figure 1 also illustrates nine mobile stations M1-M9 which are movable within a cell and from one cell to another. In a typical cellular radio system, there would normally be more than nine cellular mobile stations. In fact, there are typically many times the number of mobile stations as there are base stations. However, for the purposes of explaining the present invention, the reduced number of mobile stations is sufficient.

Also illustrated in Figure 1 is a mobile switching center MSC. The mobile switching center MSC illustrated in Figure 1 is connected to all ten base stations B1-B10 by cables. The mobile switching center MSC is also connected by cables to a fixed switch telephone network or similar fixed network. All cables from the mobile switching center MSC to the base stations B1-B10 and cables to the fixed network are not illustrated.

In addition to the mobile switching center MSC illustrated, there may be additional mobile switching centers connected by cables to base stations other than those illustrated in Figure 1. Instead of cables, other means, for example, fixed radio links may also be used to connect base stations to mobile switching centers. The mobile switching center MSC, the base stations and the mobile stations are all computer controlled.

In traditional cellular mobile radio systems, as illustrated in Figure 1, each base station has an omnidirectional or directional antenna for broadcasting signals throughout the area covered by the base station. As a result, signals for particular mobile stations are broadcast throughout the entire coverage area regardless of the relative positions of the mobile stations using the system. In the base station, the transmitter has one power amplifier per carrier frequency. Amplified signals are combined and connected to a common antenna which has a wide azimuth beam. Due to the wide beam width of the common antenna, for example 120 or 360 degrees coverage in azimuth, the antenna gain is low and there is no spatial selectivity to use to reduce interference problems.

More recent techniques have focused on using linear power amplifiers to amplify a combined signal from several carrier frequencies which is then feed to a common antenna. In these systems, the common antenna also has a wide azimuth beam. As a result, these systems also suffer from interference problems.

To overcome these problems, antenna systems have been designed which increase the gain of the transmitted signals while decreasing the

interference problems associated with a typical base station. One such antenna system is described in U.S. Patent Application No. ___, entitled "Microstrip Antenna Array", which is incorporated herein by reference. The disclosed microstrip antenna array uses several beams with narrow beam width to cover the area served by the base station. As a result, the gain of the individual beams can be higher than the typical wide beam used by an traditional antenna. Furthermore, polarization diversity can be used instead of spacial diversity to reduce fading variations and interference problems. However, in order to more accurately shape and direct antenna beams, these array antennas need to be accurately calibrated.

Summary of the Disclosure

It is an object of the present invention to improve the performance of a mobile station by increasing the accuracy of the beam shape and direction of the antenna beam. This is performed by measuring and correcting for errors and component behavior which occur in antenna array components located between the beam forming device and the radiated fields. As a result, the antenna array components do not need to be as accurately matched since any discrepancy can be corrected by using the present invention. Furthermore, the present invention can also be used to test the antenna array to verify that the components of the array are working properly before the antenna array is used by the communication system.

According to one embodiment of the present invention, a method and apparatus for calibrating the transmission of an antenna array for use in a mobile radio communication system are disclosed. First, an input signal is inputted into each antenna section one antenna section at a time. The signal transmitted by each antenna section is then measured and correction factors can be formed for each antenna section. The antenna sections are then adjusted using the correction factors so as to ensure that each section is properly calibrated.

According to another embodiment of the present invention, a method and apparatus for calibrating the reception of an antenna array for use in a mobile radio communication system are disclosed. First, an input signal is generated and injected into each antenna section of the antenna array. The signals received by each antenna section are measured and a correction signal can then be formed for each antenna section by comparing the injected signal with the measured signals. Each antenna section can then be adjusted using the correction factors so as to ensure that each antenna section is properly calibrated. The correlation factors can also be adjusted for known characteristics of the individual antenna elements.

Brief Description of the Drawings

The present invention will now be described in more detail with reference to preferred embodiments of the invention, given only by way of example, and illustrated in the accompanying drawings, in which:

Figure 1 illustrates a typical cellular radio communication system;

Figure 2 illustrates a configuration for obtaining calibration factors for the reception of an antenna array according to one embodiment of the present invention;

Figure 3 illustrates a configuration for obtaining calibration factors for the transmission of an antenna array according to one embodiment of the present invention;

Figure 4 illustrates beam forming correction according to one embodiment of the present invention; and

Figure 5 illustrates digital correction of beam forming according to one embodiment of the present invention.

Detailed Description of the Disclosure

The present invention is primarily intended for use in base stations in cellular communication systems, although it will be understood by those

skilled in the art that the present invention can also be used in other various communication applications.

According to the present invention, a calibration network is used to calibrate the components associated with each antenna section of an antenna array. Figure 2 illustrates a configuration for calibrating the reception of an antenna array in a base station configuration. The reception calibration is performed by injecting a known signal to each antenna section and measuring the output from each antenna section. As illustrated in Figure 2, a transmitter 18 generates a signal which is applied to each antenna section 10 by a calibration network 16 which is a passive distribution network dividing the generated signal to a calibration port at each antenna section. Each signal is then passed through its respective low noise amplifier 12 and the resulting signal is detected in the beam forming apparatus 14. The beam forming apparatus 14 can then generate correction factors by comparing the transmitted signal to the received signal so as to individually calibrate each antenna section of the antenna array 10. No calibration factors have to be applied if the received signals from each antenna section is identically related to the known signal injected into that antenna section. The occurrence of errors and component behavior will alter these relations which will be detected by measuring devices in the beamforming apparatus. Correction factors describing the amount of corrections needed as compensation in each antenna are then calculated. The correction factors can be described as amplitude and phase corrections or as corrections in I and Q.

A configuration for calibrating the transmission of the antenna array in a base station is illustrated in Figure 3. According to this embodiment, a beam forming apparatus 34 generates a transmit signal which is applied to each antenna section of the antenna array 30, one antenna section at a time. After the transmission signal has passed through a respective power amplifier 32, the calibration network 36 samples the resulting signal from each antenna section. The resulting signal is then fed into a receiver 38. A computation

means 40 relates the received signal from the receiver 38 with the original transmit signal for each antenna section. The occurrence of errors and component behavior will alter these relations which will be detected by the computation means and correction factors describing the amount of corrections needed as the compensation in each antenna section are calculated. The correction factors can be described as amplitude and phase corrections or corrections in I and Q.

The antenna array uses the measured correction factors to form narrow antenna beams with preferably low side lobe levels. There are several methods for using the correction factors to adjust the antenna array. As illustrated in Figure 4, the correction factors can be used to adjust the phase and/or amplitude of the signal between the beam forming apparatus 42 and the antenna array 44. In this example, the correction factors can be applied to an amplifier 46 to change the amplitude of the signal and/or to a phase shifter 48 for changing the phase of the signal. Furthermore, as illustrated in Figure 5, the correction factors can be used by the beam forming apparatus if digital beam forming is being used by adding the I and Q correction factors digitally before A/D conversion.

The present invention severely reduces the accuracies required of the components connected to each antenna section because the present invention measures and corrects for errors generated by these components. In addition, the calibration network simultaneously tests the devices associated with each antenna section so as to verify that the antenna array is working properly.

It will be appreciated by those of ordinary skill in the art that the present invention can be embodied in other specific forms without departing from the spirit or central character thereof. The presently disclosed embodiments are therefore considered in all respects to be illustrative and not restrictive. The scope of the invention is indicated by the appended claims rather than the foregoing description, and all changes which come within the

meaning and range of equivalence thereof are intended to be embraced therein.

We Claim:

1. A method for calibrating the transmission of an antenna array for use in a mobile radio communication system, said antenna array comprising a plurality of antenna sections, said method comprising the steps of:

inputting an input signal into each antenna section one antenna section at a time;

measuring a signal transmitted by each antenna section;

forming correction factors for each antenna section from said measured signals; and

adjusting output of said antenna sections with said correction factors.

2. A method for calibrating the transmission of an antenna array according to claim 1, wherein said correction factors adjust the phase of the output of the antenna sections.

3. A method for calibrating the transmission of an antenna array according to claim 1, wherein said correction factors adjust an amplitude of the output of the antenna sections.

4. A method for calibrating the transmission of an antenna array according to claim 1, wherein said correction factors adjust the phase and amplitude of the output of the antenna sections.

5. A method for calibrating the transmission of an antenna array according to claim 1, wherein the correction factors are applied to signals between a beamforming means and the antenna sections.

6. A method for calibrating the transmission of an antenna array according to claim 1, wherein the correction factors are applied digitally to a beamforming means.

7. A method for calibrating the reception of an antenna array for use in a mobile radio communication system, said antenna array comprising a plurality of antenna sections, said method comprising the steps of:

generating an input signal;

injecting said input signal into each antenna section;

measuring a signal outputed by each antenna section;

forming correction signals from each antenna section by comparing the injected signal and said measured signals; and

adjusting said antenna sections with said correction factors.

8. A method for calibrating the reception of an antenna array according to claim 1, wherein said correction factors adjust the phase of signals received on each antenna section.

9. A method for calibrating the reception of an antenna array according to claim 1, wherein said correction factors adjust an amplitude of signals received on each of said antenna sections.

10. A method for calibrating the reception of an antenna array according to claim 1, wherein said correction factors adjust the phase and amplitude of signals received on said antenna sections.

11. A method for calibrating the reception of an antenna array according to claim 1, wherein the correction factors are applied to signals between a beamforming means and the antenna sections.

12. A method for calibrating the reception of an antenna array according to claim 1, wherein correction factors are applied digitally to a beamforming means.

13. A system for calibrating the transmission of an antenna array for use in a mobile radio communication system, said antenna array comprising a plurality of antenna sections, said system comprising:

means for inputting an input signal into each antenna section one antenna section at a time;

means for measuring a signal transmitted by each antenna section;

means for forming correction factors for each antenna section from said measured signals; and

means for adjusting output of said antenna sections with said correction factors.

14. A system for calibrating the transmission of an antenna array according to claim 13, wherein said correction factors adjust the phase of the output of the antenna sections.

15. A system for calibrating the transmission of an antenna array according to claim 13, wherein said correction factors adjust an amplitude of the output of the antenna sections.

16. A system for calibrating the transmission of an antenna array according to claim 13, wherein said correction factors adjust the phase and amplitude of the output of the antenna sections.

17. A system for calibrating the transmission of an antenna array according to claim 13, wherein the correction factors are applied to signals between a beamforming means and the antenna sections.

18. A system for calibrating the transmission of an antenna array according to claim 13, wherein the correction factors are applied digitally to a beamforming means.

19. A system for calibrating the reception of an antenna array for use in a mobile radio communication system, said antenna comprising a plurality of antenna sections, said system comprising:

means for generating an input signal;

means for injecting said input signal into each antenna section;

means for measuring a signal outputed by each antenna section;

means for forming correction signals from each antenna section by comparing the injected signal and said measured signals; and

means for adjusting said antenna sections with said correction factors.

20. A system for calibrating the reception of an antenna array according to claim 19, wherein said correction factors adjust the phase of signals received on each antenna section.

21. A system for calibrating the reception of an antenna array according to claim 19, wherein said correction factors adjust an amplitude of signals received on each of said antenna sections.

22. A system for calibrating the reception of an antenna array according to claim 19, wherein said correction factors adjust the phase and amplitude of signals received on said antenna sections.

23. A system for calibrating the reception of an antenna array according to claim 19, wherein the correction factors are applied to signals between a beamforming means and the antenna sections.

24. A system for calibrating the reception of an antenna array according to claim 19, wherein correction factors are applied digitally to a beamforming means.

Fig.1

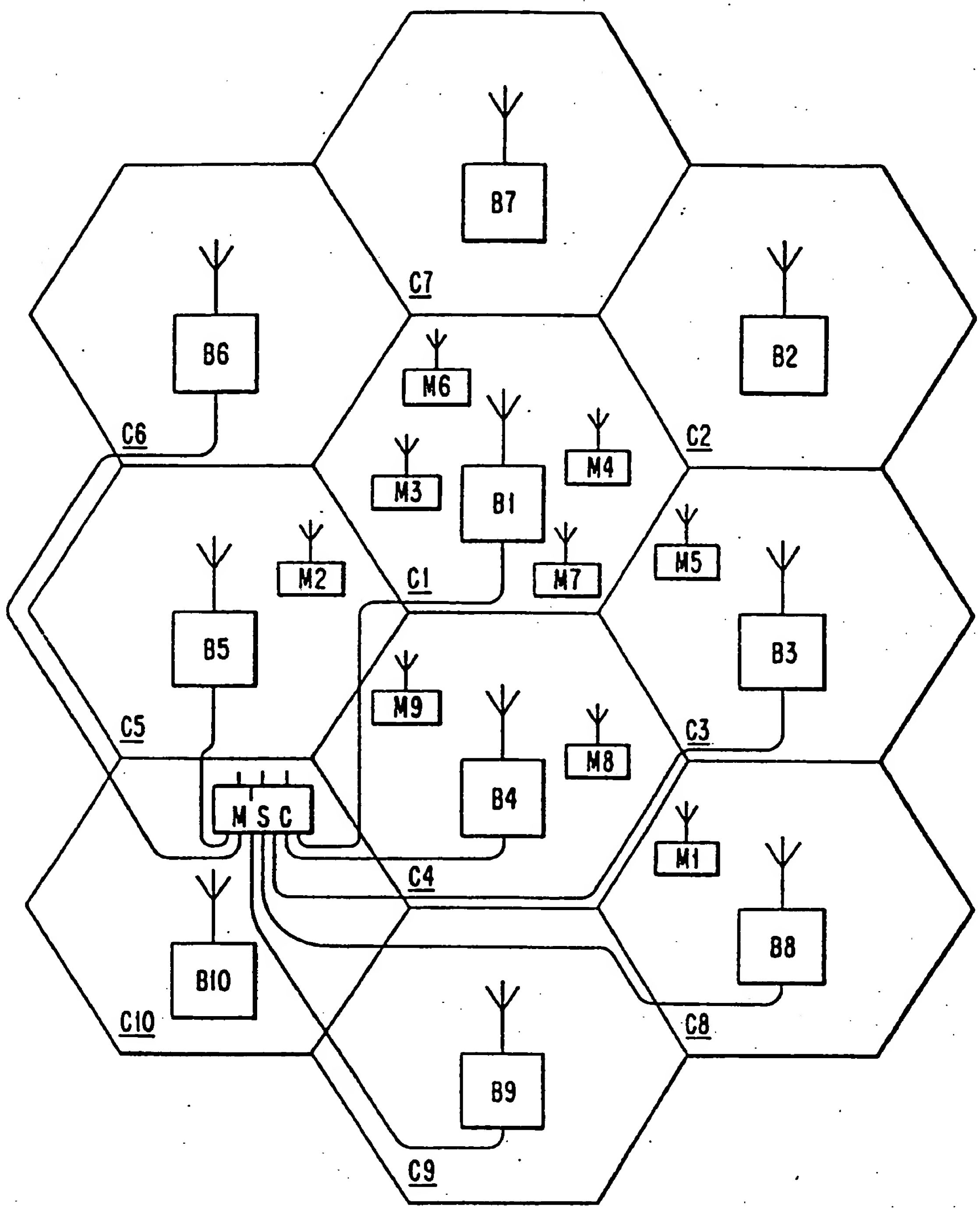
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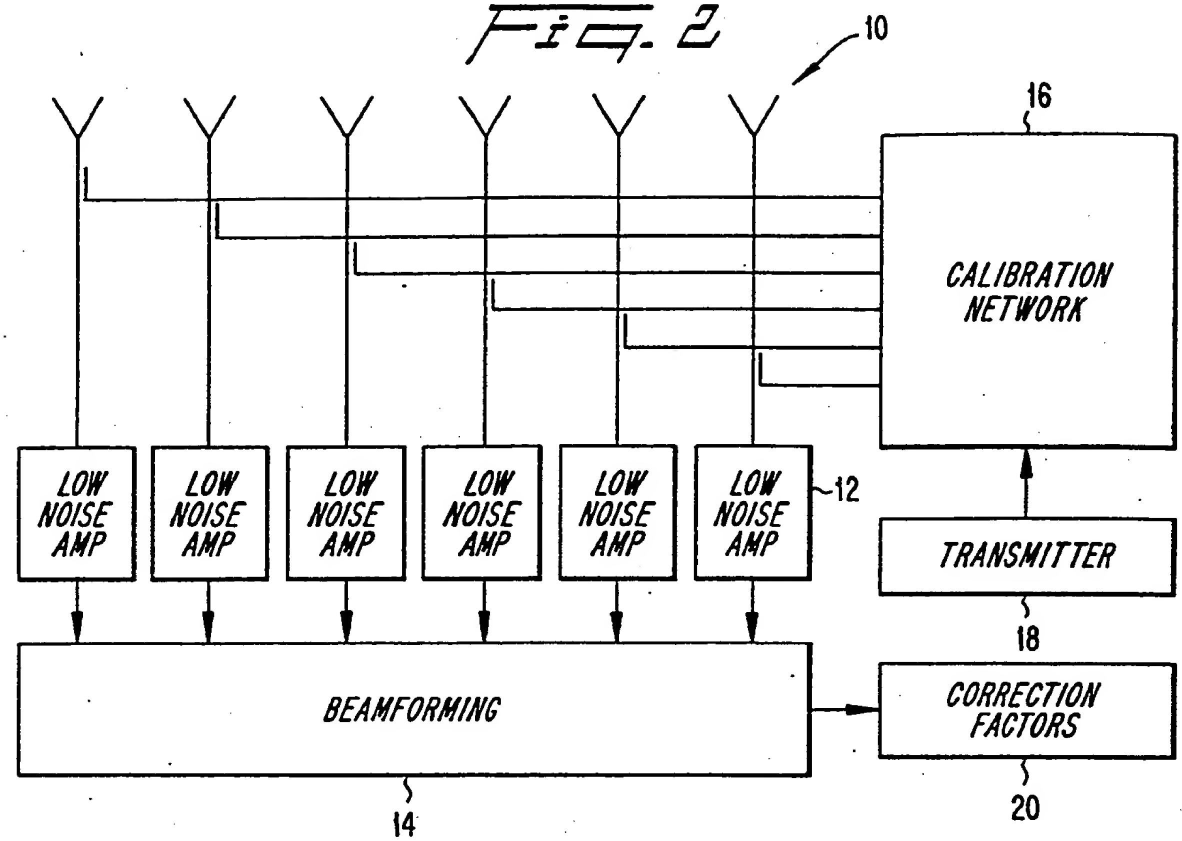
Fig. 2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LOW NOISE AMP
LOW NOISE AMP
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TRANSMITTER
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BEAMFORMING
CORRECTION FACTORS
14
20

Fig. 3

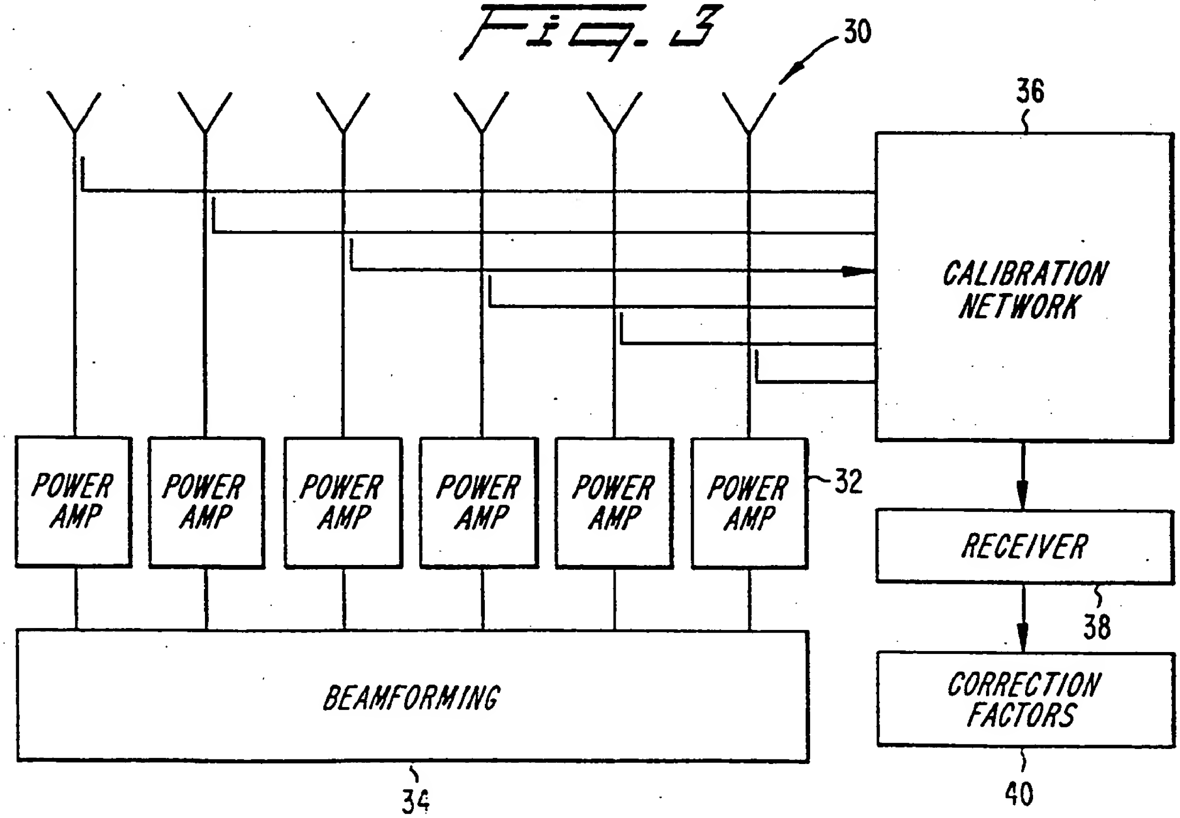
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Fig. 4

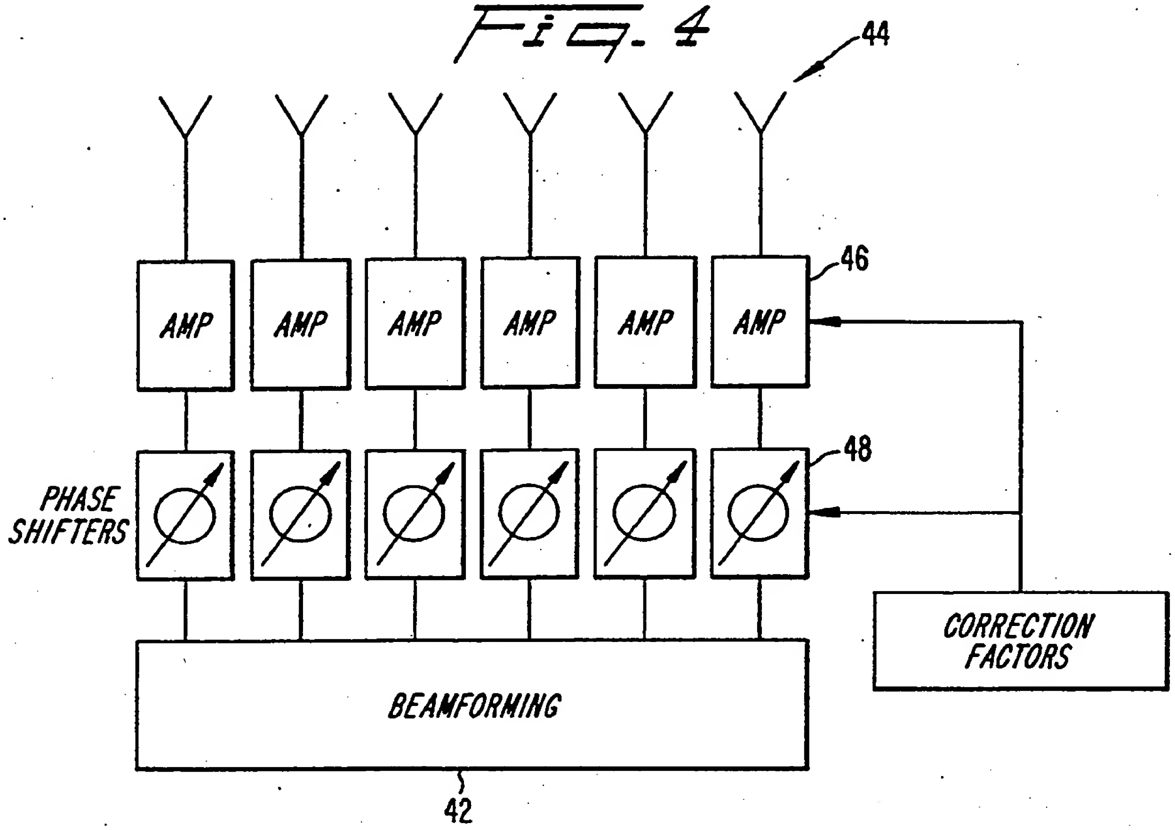
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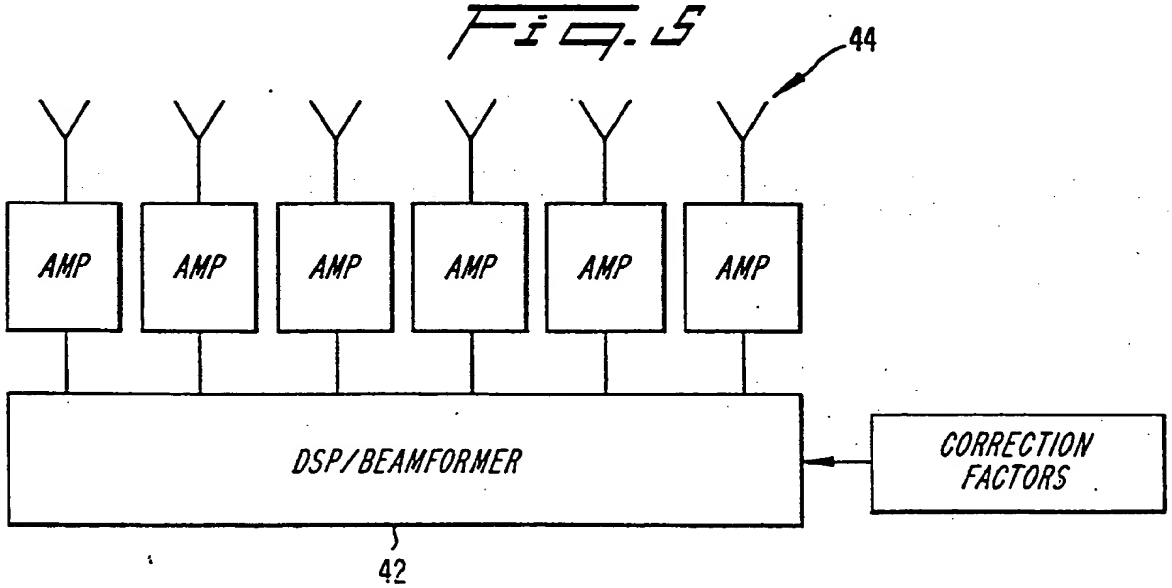
Fig. 5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DSP/BEAMFORMER
CORRECTION
FACTORS
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 95/00627

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01Q 3/26, G01R 29/10
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01Q, G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, CLAIMS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5063529 A (CHARLES W. CHAPOTON), 5 November 1991 (05.11.91), column 5, line 36 - column 6, line 11, abstract --	1-24
A	US 5027127 A (HAROLD SHNITKIN ET AL.), 25 June 1991 (25.06.91), column 3, line 5 - line 61, figure 1, abstract --	1-24
A	GB 2224887 A (MITSUBISHI DENKI KABUSHIKI KAISHA), 16 May 1990 (16.05.90), page 5, line 19 - page 10, line 9, abstract --	1-24

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
20 November 1995	21 -11- 1995

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INTERNATIONAL SEARCH REPORT

International Application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5248982 A (VICTOR S. REINHARDT ET AL.), 28 Sept 1993 (28.09.93), column 3, line 28 - column 4, line 12, abstract	1-24

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INTERNATIONAL [redacted]RCH REPORT
Information on pat[redacted]nily members

02/10/95

Internati[redacted]pplication No.
PCT/SE [redacted]/00627

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		US-A- 4994813	19/02/91
		JP-A- 2104104	17/04/90
US-A- 5248982	28/09/93	NONE	